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23 OCT. 1915
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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION
BULLETIN 122

THE SMUTS OF GRAIN CROPS

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IMPERIAL BUREAU
17 SEPT. 1930
OF MYCOLOGY

UNIVERSITY FARM, ST. PAUL
REVISED AND REPRINTED FEBRUARY 1914

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THE SMUTS OF GRAIN CROPS

WHAT THE SMUTS ARE

The smuts of grains, familiar to every farmer, are diseases of parasitic origin. They cause black masses of powder where the grain of wheat, oats, or barley ought to be, or on the leaves, ears, or other parts of corn. This black mass may be in a compact ball, as in the stinking smut of wheat; or it may be a loose, powdery mass, as in the loose smut of wheat or in the oat smut. In wheat, the stinking smut mass has an odor like that of dead fish, easily detected in the field or in the harvested grain.

The smut parasite is a fungus plant composed of delicate, colorless threads, which live inside of the grain plant and are so small that they can be seen only by the aid of the microscope. The fungus does not produce seeds, but reproduces itself by means of spores as shown in Figure 2. The smut dust is composed of these spores. Each spore is so small that in some common smuts 5,000 of them placed side by side would make a line but an inch long. A smut mass of corn, an inch in diameter, contains, therefore, many millions of spores. The spores are single round cells, with thick walls, so that they are well protected against drying up or other injury. When they encounter favorable conditions they germinate and thus reproduce the disease. The method of germination is shown in Figure 1. A small thread is produced from the spores, grows in length, and may branch. One of these fungus threads gets into the grain plant, and there keeps on growing and branching. It gets food by stealing from the grain plant. The threads get into the grain or leaf, and there grow very fast; and finally they break up into the small round spores again, and the smut mass is thus produced.

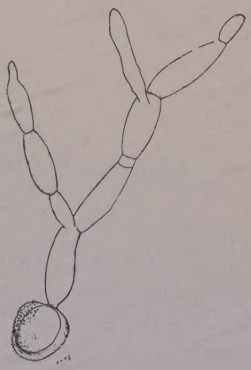

Fig. 1. Spore of Loose Smut of Wheat
Sending out a germ tube which has begun to branch.
Enlarged to about 600 times natural size.

In a word, then, the smut is a parasite composed of tiny threads like those shown in Figure 3, which live inside of the plant, steal their nutrition from it, and finally reproduce by means of spores. These spores can each produce a thread which may start the disease in another plant.

THE LIFE OF THE SMUT

It must first be noticed that all smuts are not alike. There are different kinds, and each has its own way of living. Moreover, the corn smut does not cause smut in wheat, oats, or barley. Neither does the oat smut cause smut in wheat, barley, or corn. Each smut is distinct. Smut dust from corn can be mixed with wheat without producing any smut in the wheat. Furthermore, each smut has its own peculiar habits of life and may differ from other smuts in many ways. For instance, corn smut gets into any part of the corn plant, while stinking smut can get into the wheat plant only when that plant is sprouting from the seed. On the other hand, two or more smuts may have similar habits of life, although each is a distinct disease. For instance, the stinking smut of wheat and the covered smut of barley both infect or get into the grain plant in the sprouting stage, and both can be prevented by the same treatment; but the barley smut can not get into the wheat plant and the stinking smut can not get into the barley plant.

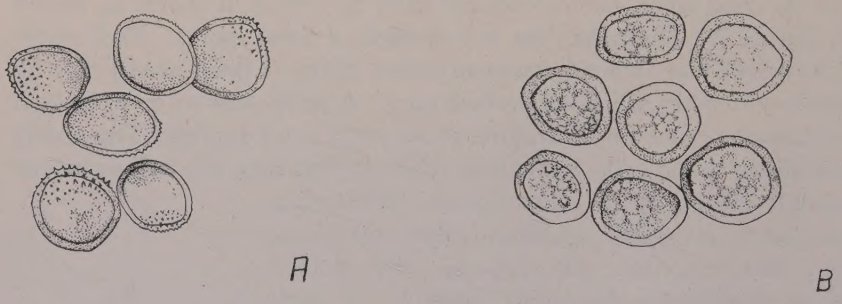

Fig. 2. Spores of Common Smuts
A Loose Smut of Wheat. *B* Smut of Oats.
Enlarged to 1300 times natural size.

In treating plant diseases it is well to learn the reason for the treatment used. These reasons are almost always found in the life history of the disease. It will be best, therefore, to recite the life history of the common grain smuts. As pointed out above, two or more smuts may have similar life histories although they are different and distinct smuts which can not be transferred from one kind of grain to another.

The common smuts of grains in Minnesota can be arranged in three groups, so far as the life histories are concerned. The smuts of each group have in general a similar method of living. As a result, the treatments for the smuts in any one group are quite similar. For instance, the life histories of the oat smut, the stinking smut of wheat,

the covered smut of barley, and grain smut of sorghum, are all alike in a general way; and the treatments for their prevention are similar; for instance, steeping or spraying the seed with a formalin solution.

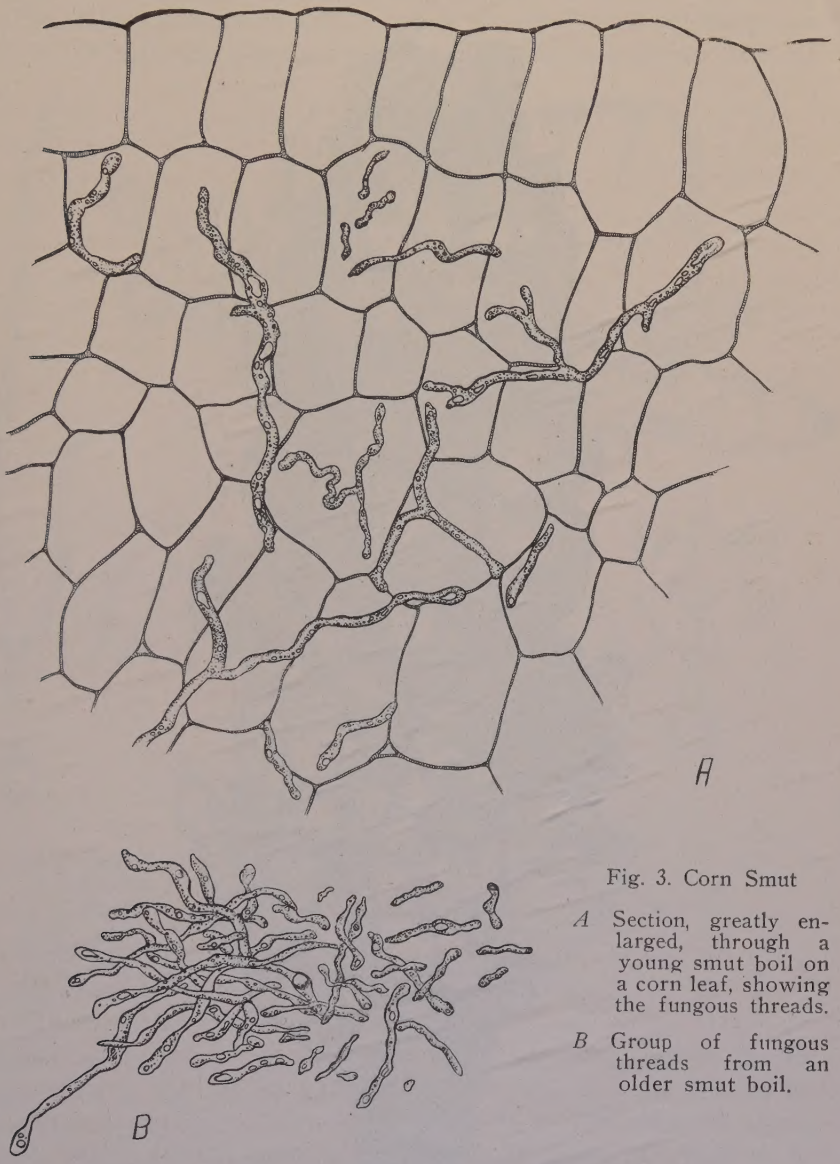

Fig. 3. Corn Smut

A Section, greatly enlarged, through a young smut boil on a corn leaf, showing the fungous threads.

B Group of fungous threads from an older smut boil.

LIFE HISTORY OF CORN SMUT

The smut mass of corn smut varies greatly in size and may be found on any part of the plant. The smut spores which come from

this mass are blown out by the wind and may, of course, be carried to a considerable distance, or the smut mass itself may be broken off and thrown on the ground or perhaps into a refuse or manure pile. The

Fig. 4. An Ear of Corn Reduced to a Smut Mass

spores in the manure pile or on the ground may start to grow. When they grow they send out small, delicate, colorless tubes; and these little tubes may form more spores, so that in a fresh manure pile the spores may actually increase in number during the winter. However, as the manure pile grows old, the spores may die; hence old manure is better for fertilizing purposes than fresh manure because less likely to

Fig. 5. Corn Smut

A A smut boil.
B Individual spores from the boil.
C A smut spore germinating and producing more spores (sporidia).
D Group of sporidia.
E Sporidia germinating.
F A smut spore sending out a long infection thread.
All except *A* enlarged to about 600 times natural size.
For later stages, see Figure 3.

scatter smut spores. Having lived over the winter, either in the ground or in the manure pile, in early summer the smut renews its growth. Again its tiny spores are picked up by the wind and blown about. Some of these spores are blown upon a young corn plant or on a young part of an older corn plant. Such a spore will germinate, producing a small thread as shown in Figure 5, which will grow into the corn plant, penetrating the skin or epidermis. When the delicate little

thread gets inside the corn plant it continues to grow both in length and by branching, and soon produces a complex network of threads as shown in Figure 3. These threads stimulate the corn plant, so that it grows very fast in their neighborhood. All this time the threads are still growing and feeding on the corn plant. When this has gone on for some time, the smut threads begin to break up into small pieces and each piece rounds up and becomes a spore. The whole boil-like structure turns black and powdery, and we have again the spore mass or smut mass.

Of the common smuts attacking Minnesota grains, none is known which has a life history similar to that of the corn smut.

Details for the treatment of corn smut are given later on. It should be noted here, however, that on account of the life history there would be no necessity for treating the seed of corn for smut. This smut must be controlled in the handling of the soil and the manure pile.

LIFE HISTORY OF SMUTS OF SMALL GRAINS AND SORGHUM

The life histories of four smuts common on Minnesota grains are in all essential matters similar, so that they can be discussed under one head. Of course there are slight differences even in the life histories, but these can be disregarded so far as this bulletin is concerned.

In all cases the spore masses are found in the kernels of the grains. In oat smut and the covered smut of barley, the chaff is also smutted to a certain extent. When the spore mass is broken, the spores reach the grain, as in threshing wheat and sorghum. A single grain of wheat or barley may have clinging to it many hundreds or even thousands of these small spores. When the seed with the spores on it is planted in the spring and the grain sprouts, the smut spores also sprout by sending out delicate, colorless threads. Some of these tiny threads grow into the grain sprout, piercing the protecting leaves and penetrating to the center, as shown in Figure 6. It is here that the so-called growing-point of the grain plant is located. This is the growing tissue which forms the leaves and new part of the stem of the plant. The smut threads live in this growing-point and continue to grow with it until the grain is ripe. The last thing that the growing-point produces is the head of the grain; and when this is still very young, even before it is out of the "boot," the smut threads can be found in all parts of it. As the head fills and becomes mature, the smut threads increase, and finally at about harvest time they break up into small pieces, each piece becomes a spore, and the spore mass thus takes the place of the grain in a healthy plant.

There are some differences, as noted above, in the minor points of

the life histories of these smuts. For instance, the stinking smut of wheat gets on the healthy grain usually only during threshing or later. The oat smut, however, is scattered in the summer, the spores being blown by the wind from a smutty plant to a healthy plant, where they lodge on the young grain. These differences will be discussed more in detail below.

As to the treatment of this class of smuts, it will immediately be seen that the growing plant which already has the smut inside of it can not be cured, and also that the point of attack for treating is the seed, and all that is necessary to prevent a recurrence of these smuts is to

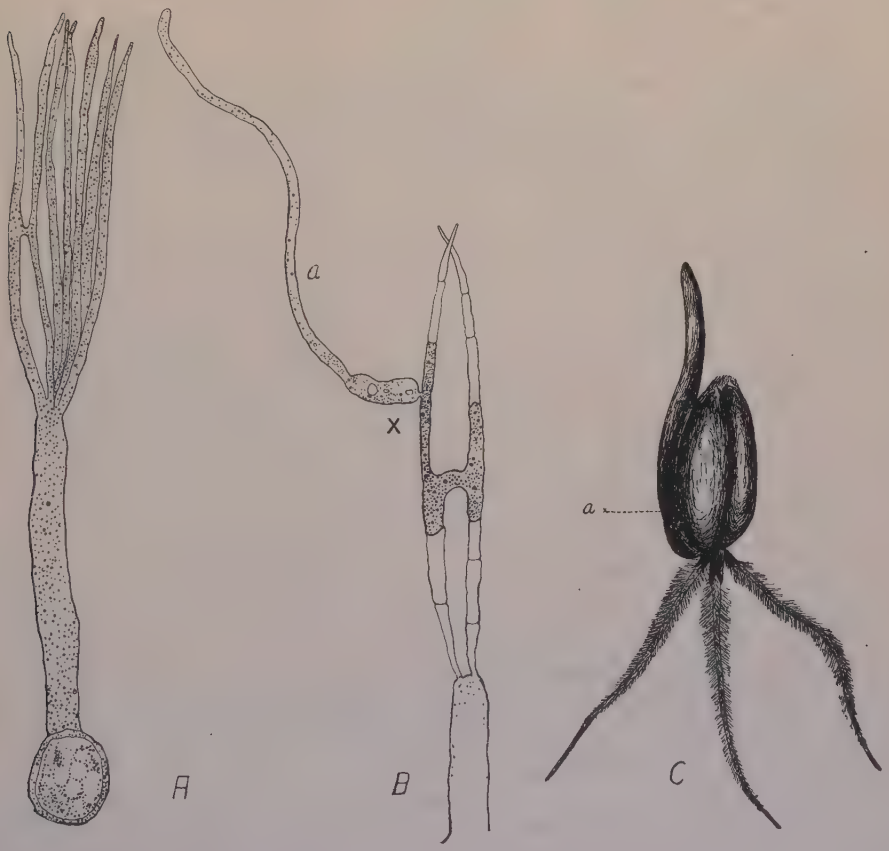

Fig. 6. Bunt or Stinking Smut of Wheat

A Germinating spore producing more spores (sporidia) at the tip of the germ tube.

B Sporidia which have united; one has produced another spore (secondary sporidium) at *X* and this is sending out an infection thread to infect the young sprouting wheat plant at *a* in *C*.

A and *B* enlarged to about 500 times natural size.

wash off or kill the spores that are on the seed before planting. If the spores are entirely removed, either by washing off or by killing with some solution, there will be no smut in the following crop.

LIFE HISTORY OF LOOSE SMUT OF WHEAT AND LOOSE SMUT OF BARLEY

These two smuts can very readily be distinguished from the other smuts on these two grains. They are sometimes called early smuts, since they discharge their spore masses earlier in the season. The spore masses are looser than those of the second group of smuts and open up very early. They begin to appear as soon as the plants head out and break even before they get out of the "boot." The wind blows them over the field. It will be noticed that the spores are distributed at exactly the time when the grain plant is in flower, that is, at about heading-out time. Some of the spores are blown to the heads of healthy plants, when the latter are in the flowering stage, and some are blown or are washed between the chaff into the flower. They get into the flower at about the time the seed begins to form and may lodge upon the outside of the young seed-forming organ in the flower. Here the spore grows by sending out, as in other cases, a delicate tube, and this tube grows into the very young seed. (See Figure 7.) Now, even in a very young seed, there is a little grain plant, and the smut threads grow into this grain plant. Here they remain while the seed grows in size and fills out; and when this seed is ripe, although it looks like an ordinary healthy seed, it has inside of its little plantlet the threads of the smut plant. Such a seed looks exactly like a healthy seed, and from the outside there is no way of detecting any difference. It is well to compare such a seed with a seed on which spores of the preceding group of smuts are clinging. In the case, for instance, of stinking smut of wheat, we would have a wheat seed with spores on the outside; while in the loose smut of wheat we have a wheat seed with the smut plant inside of the little plant in the seed. It will be seen at a glance that the loose smut, with its smut plant inside of the seed, is more difficult to treat than the seed with the smut spores on the outside. This is the reason why ordinary treatment, such as is recommended in the preceding group of smuts, has no effect on the loose smut of barley or on the loose smut of wheat, because such treatment does not reach inside of the infected seed. When the infected seed with its smut plant inside is sown it sprouts just as an ordinary healthy seed. As the young plant in the seed begins to grow, the smut threads inside of this plant also begin to grow and they keep pace with the growth of the plant as shown in Figure 8. From this point on, the behavior of

Fig. 7. Loose Smut of Barley

A Normal head of barley.
B Smutted head of barley.
C Smut spores; greatly enlarged.
D Spore germinating; greatly enlarged.
E (*a*) Head of barley, showing open glumes at the stage when the smut spores are probably blown in.
(*b*) A single flower.
F Longitudinal or lengthwise section through a barley kernel, showing the young embryo plantlet at *a*, its growing-point at *c*; food for the young plantlet at *d*, seed coat shown at *b*. The smut threads live in the young plantlet *a* during the winter, and get into the growing point *c* while it is still inside the seed. (For detail of threads in growing-point, see Figure 8. Compare with Figure 6, noting difference in the stage at which infection takes place.

this smut is like that of the smuts of the preceding group; that is, the smut threads live in the growing-point of the grain plant and remain there until the head is formed. Then the smut threads grow on through the young kernels and chaff of the new head, and finally break up into small pieces, which are rounded up into little spores, and we have again the smut mass in the field.

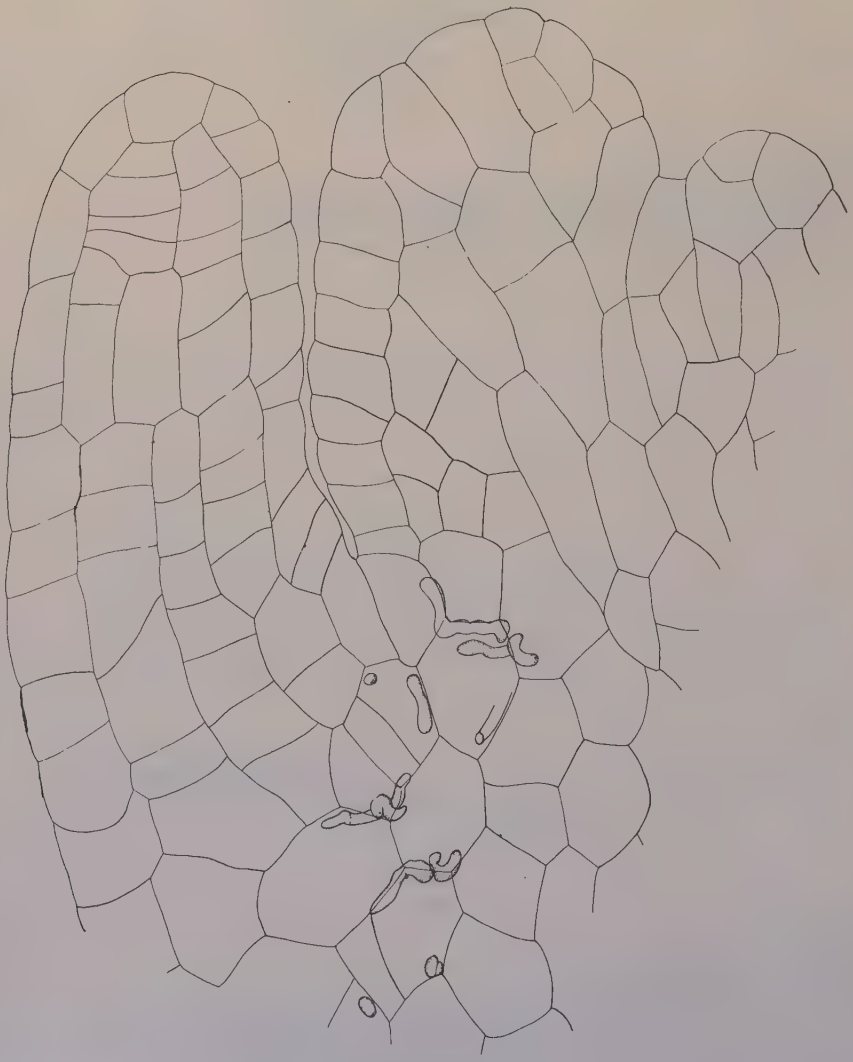

Fig. 8. Growing Point of the Stem of Barley
Much enlarged, showing fungous threads. (After Hecke.)

Since an infected seed has no spores on the outside, but has the smut inside of the seed, some methods of treatment have to be devised other than those used for smuts of wheat and barley. These methods are briefly as follows: The seed is soaked in cold water for several hours. In its water-soaked condition, heat can be carried through the seed more uniformly and quickly than when it is dry. This seed is soaked again, this time in hot water, killing the smut plant inside of the seed, while the seed is not at all, or only slightly, injured. For further details, see below.

Since the treatment for one group of smuts may have no effect on the other, it is absolutely necessary for a farmer to know with which smut he is dealing. It then becomes an easy matter to apply the proper remedy. For instance, in treating smut in barley, a farmer who treats his barley with formalin will get rid of the covered smut of barley, but will *not* get rid of the loose smut of barley. The same is true of wheat. In order to get rid of the loose smuts of these crops, the modified hot-water treatment described on pages 21 and 22 should be used.

There is another smut, not described above, which is found on sorghum plants, but it has not yet appeared to any extent in Minnesota. It is known as "head smut of sorghum." The life history of this smut has been determined recently, but not published, and control methods are not yet definitely known.

KINDS OF SMUT AND THEIR TREATMENTS

CORN SMUT

Every farmer is familiar with corn smut. The largest masses are sometimes over 6 inches in diameter and are usually found in the ear as shown in Figure 4. Smut is also found in the tassel, on the leaves and stem, and even on those roots which hold the corn plant to the soil. The smut mass is blackish and is at first covered by a whitish film, which soon breaks and liberates the spore powder, which is blown about by the wind. How these spores live through the winter and then infect the corn plant has been described above. In general, there are two ways by which the spores get back on the land, ready to infect the next year's crop. First, they may be scattered by the wind, or the smut masses may be left on the field. Second, the smut dust may get into the fodder and pass through the alimentary canals of the cattle without being injured and may thus get into the manure pile. Or again, the smut masses may be thrown into the refuse or manure pile. In either case they may be carried back to the soil when it is manured. It is an important fact that the smut spores not only may live through the winter in the manure pile, but that they may actually increase in number when the pile remains at the proper temperature. Fresh manure containing smut is therefore very likely to increase smut in a corn field. The smut may live for several years in a manure pile, but will gradually die out. For this reason, old manure is much better for fertilizer on a corn field than fresh manure.

Since the smut masses that are left in a corn field may assist in spreading the disease, they should be cut out during the growing season, before they have fully opened up and spread their spores, and then collected and burned. They should not be thrown on the manure heap or refuse pile, thence to be carried back to the land.

Rotation of crops is valuable in preventing corn smut. The reason for this is plain. The corn smut in the soil will not live many years, and that which is in the soil will not damage any other farm crop. After several years corn may again be planted, with less danger, since the smut in the soil will have at least partly died out.

Treatment of seed has not been found useful. The smut does not get into the seedling plant, as in the stinking smut of wheat, and hence seed treatment does not seem necessary.

The sugar corns seem to have more smut than the field corns, though no varieties, even of the latter, are known that are free from smut. Special care should therefore be exercised with the sugar corns.

Corn smut is found in almost every part of Minnesota where corn is grown. Smut is worse in some years than in others, due probably to favorable weather conditions. Although the loss is usually not as great as in some states further south and east, it is nevertheless considerable. Most farmers consider the loss too small to demand any attention, yet the aggregate to the State is undoubtedly large. It should be noticed that the loss is not measured by the deformed ears alone, but also by the loss in vigor and yield in plants where other parts are prevented from doing their work properly on account of smut.

WHEAT SMUTS

There are two common smuts of wheat: the stinking smut, or bunt, and the loose smut. These are easily distinguished in the field. The stinking smut causes most damage, but the loose smut is just as widely distributed and, in the aggregate, causes considerable damage every year.

Stinking Smut or Bunt

Bunt is commonly spoken of merely as smut. The smut masses are formed only in the kernel of wheat. Usually, when a plant is smutted, every head of that plant, and often every kernel in every head, is affected. Sometimes one or more heads of a smutted plant, and quite frequently some kernels in a smutted head, remain normal. The smut mass is compact and has a rather firm wall around it which does not break very easily in the field. In this it differs from the loose smut, which breaks and spreads its spores very early, in fact as soon as the head comes out of the "boot," as shown in Figure 9B. The stinking smut is usually not noticed until the grain is well headed and almost ripe. With a little practice smutted heads can easily be distinguished from sound heads. The chaff usually spreads out more than in the healthy heads, and the smutted kernels or smut balls can often be easily seen. The smutted heads are light and usually stand erect. When a kernel is pressed between the fingers, it breaks readily, and the oily or dusty smut mass is released. The odor, like that of decaying fish, can easily be detected in the field or in harvested grain in small amounts and will often be carried for some distance. When a kernel is broken between the fingers, the odor is very pronounced. When grain from a smutted field is threshed, many of the smut balls are broken, and the healthy grains are smeared with smut dust.

As far as is at present known, there is little danger, in Minnesota, of infection by stinking smut from the spores that get into the soil, such as is commonly the case in corn smut. In an experiment at this

Station, spores were scattered over and raked into the ground in the fall, and seed carefully treated with formalin was sown in the spring. Only a fraction of one per cent of smutted heads resulted. A rotation of crops, such as certainly ought to be practiced, will probably remove practically all danger of such infection.

Before beginning any treatments for stinking smut of wheat, unbroken smut balls should always be removed. If this can not be done by fanning, the grain can be poured into a barrel containing cold water. It should then be thoroughly stirred, and the smut balls will come to the surface, when they can be skimmed off. They should be

Fig. 9. Loose and Stinking Smuts of Wheat

A Normal head of wheat, showing kernels below.
B Head of wheat, affected by stinking smut, showing smut balls at *a*.
C Loose smut.

burned or otherwise removed, so that they will not get into the grain again.

It will be readily seen that, if a clean crop is desired, seed grain which has smut on it must be treated some way to remove the smut spores. This can be done by killing the spores with hot water or chemical solutions.

After clean seed is obtained it must be kept clean—not put into bins or sacks or seeders that have smut in them. If it comes in contact with smut again it will produce smutty grain. Furthermore, a farmer must be careful even when he has no smut in his field. A threshing machine which has just threshed smutty wheat may bring smut into a clean crop. Many farmers wonder why they get smut where they had none before. Careless handling of the grain in smutty sacks, or through dirty separators, is often the cause. Again, when a farmer gets new seed, he should be sure that it is not from a smutted crop. The smut in the grain may be so small in amount that it can not ordinarily be detected, and yet enough may be present to cause considerable smut in his crop.

Clean seed is the important thing—seed free not only from weeds, but from smut as well. If there is any doubt at all as to the cleanness of the seed, it should certainly be treated.

DAMAGE DONE BY STINKING SMUT

This is one of the most destructive smuts attacking Minnesota grain crops. It is impossible to estimate accurately the amount of damage done every year. Many cars of smutty wheat are received yearly at the Minneapolis market. This usually means a loss of several cents per bushel to the farmer, although the wheat may be excellent except for the smut. This loss does not tell, however, more than a small part of the story. When smut is present in large amounts, the yield per acre is reduced considerably. The smut may often take half of the crop, and even more, and leave the rest of the crop inferior. Such smutted grain must be cleaned at the mills, and the additional expense lowers the value of the wheat. Unless it is treated, smutted grain can not, of course, be used for seed without a loss in the succeeding crop. It is probably safe to say that Minnesota farmers lose over one per cent of their crop, or upwards of one million dollars, through smut every year. *Every cent of this loss can be prevented by the treatment of the seed* as described above. This insurance can be obtained at the price of one or two cents per acre.

TREATMENT

A number of successful methods for treating stinking smut are known and have been practiced. Only the simplest and most efficient

methods will be described here. Any farmer preferring other methods should consult with the writers about them. Stinking smut can be entirely prevented by any of the following treatments:

(a) Dipping the grain in a solution of formalin.
(b) Sprinkling the grain with a solution of formalin.
(c) Dipping the grain in a bluestone solution.
(d) Steeping the grain in hot water.

(A) DIPPING IN A FORMALIN SOLUTION

Materials needed—

Formalin
A 45-gallon barrel
A bushel basket lined with wire screen or sacking, or clean sacks
A clean floor or canvas on which to put the treated seed

Buy of a reliable druggist guaranteed formalin (40 per cent solution of formaldehyde) which you know is standard in strength. Farmers can well coöperate and buy guaranteed formalin in bulk directly from the manufacturers. It is essential that the formalin be full strength; if there is any doubt on this point, send a sample of it to the Chemist, University Farm, St. Paul, where it will be tested free of charge. Pour 1 pint (1 pound) into from 40 to 45 gallons of water in a large barrel or tub and mix it thoroughly. Put the grain to be treated either in bushel baskets, lined with wire or sacking, or in clean sacks. It is best not to have more than a half-bushel in the sack or basket. Plunge the sack or basket into the solution until completely submerged. Then raise it, allow it to drain for a moment, and plunge it in again. Be sure to agitate it so that every grain gets wet. Do this several times, and then allow the solution to drain back into the barrel, and put the sacks in a clean place where the rest of the solution will drain off, or dump out the grain on a clean floor or canvas and cover the pile with sacking for from 12 to 24 hours. Then remove the sacking and let the grain dry so that it can be run through the seeder. The grain in sacks can either be spread out to dry in a clean place or it may be dried in the sacks, provided they do not contain too much grain. Be sure not to let the grain sprout before seeding. Also be sure that after it is treated it is not again allowed to get smut on it from bins or sacks. Do not let the treated grain freeze while it is still moist. Grain can be treated several months before seeding, but must then be thoroughly dried, so that it will not sprout or mold. To clean a floor or bin, scrub well with a strong solution of 1 pound of formalin in 10 gallons of water. Sacks and canvas can best be cleaned by boiling for a short time in water. Seeders can be cleaned by washing out with a strong solution of formalin.

Formalin as ordinarily used is not poisonous, although the strong

fumes will make the eyes smart and a strong solution will harden the skin temporarily. Treated grain should not be fed to cattle.

In the dipping treatment, the dipping is continued until the solution is used up. Forty gallons of the solution will treat 40 bushels or more of wheat. The seed can be left in the solution at least an hour without injury. Until it is perfectly dry, the treated seed will be somewhat swollen. If planted in this condition, therefore, the seeder must be set to allow more seed per acre. To figure this properly, measure a certain amount before treating and again before seeding and sow accordingly. The grain will often swell to 1⅓ or 1½ times its former bulk.

(B) SPRINKLING WITH FORMALIN SOLUTION

Materials needed—

Same as under dipping treatment, except that a dipping basket is not needed.

In addition: Shovels for mixing the grain
An ordinary garden sprinkling-can

Remove smut balls as directed above. Prepare the solution as for the dipping treatment. Place the grain to be treated in a clean wagon-box or on a clean canvas or floor, making a layer several inches thick. Sprinkle the solution over the grain and then shovel or rake the grain so as to mix it thoroughly; then sprinkle and shovel again. Continue this until the seed is all thoroughly moist. Then shovel the whole lot into one pile and cover over night with sacking. Then spread out to dry sufficiently before sowing. When drying the grain, do not deposit it in a layer more than a few *inches* thick. The precautions recommended above, under the dipping treatment, for handling after treatment, must be carefully followed: Do not get smut on the clean grain, do not let it freeze or sprout, and allow for swelling in sowing. Forty gallons of the solution will treat from 50 to 55 bushels of wheat.

(C) STEEPING THE GRAIN IN HOT WATER

The hot-water treatment is cheap and effective. It requires more care than the formalin treatment, and a careless farmer is more liable to injure his grain. It has this great advantage over the formalin method: no chemicals are necessary, and the farmer does not stand the chance of injury to his crop by buying a chemical which is not of standard strength. In the hot-water treatment everything is under the control of the farmer. He must have, however, a reliable thermometer; the ordinary cheap thermometer is not safe.

Materials needed—

Two ordinary vinegar (or other wooden) barrels or large tubs
Several large buckets

An accurate thermometer*
A basket or sacks, as described for dipping treatment
A paddle for keeping the water stirred
Clean floor space or clean canvas

Remove smut balls as directed above. Mark the barrels or tubs No. 1 and No. 2. Keep water in No. 1 at about 125° or 130° F. (not higher). Keep water in No. 2 between 130° and 135° F.—be very careful about this. Have several buckets of very hot water and a supply of cold water always on hand. The temperature in the tubs may be raised by adding hot water and lowered by adding cold. Be sure, when adding hot water, not to pour it directly on the seed, as this will surely injure it. Also be sure to stir the water when adding either hot or cold, in order to have all of the water at the same temperature. Remember that the larger the quantity of water used in proportion to the grain, the easier it will be to keep the temperature constant. Therefore either use large barrels, or vats if possible, or else treat only small amounts of seed at one time. Do not let the temperature of the water get above 145° F. If it falls below 132°, keep the seed slightly longer in the solution. Do not keep the seed in the water more than twenty minutes and do not let the temperature get below 125°. Take the temperature at about the level at which the seed is kept.

The seed to be treated is placed in a basket or sack. In an ordinary barrel not more than half a bushel should be treated at one time. First dip the basket (or sack) of grain in barrel No. 1, in order to bring the seed up to about the right temperature, so that when it is put into barrel No. 2, the temperature of the water in No. 2 will not be greatly lowered. Leave the basket in No. 1 for about a minute, raising and lowering it so that the water will get quickly to all of the seed. Then transfer the basket to barrel No. 2 and leave it in this barrel for ten or fifteen minutes. Be very careful to keep the temperature of No. 2 within the limits given above. The basket must be raised and lowered frequently, so that the water will get between the grains. There may be a difference of 5° F. between the grain in the middle and outside of a half-bushel of wheat if it is not thoroughly agitated. The temperature is regulated as described above. If the water goes above 145° F., the grain should not be used for seed. If it goes down to 125° for any length of time, all the smut may not be killed. When the grain has been treated in No. 2, lift the basket out of the barrel and allow it to drain for a few minutes and then spread it on a clean floor or canvas to dry.

*Thermometers with certification of the Bureau of Standards at Washington, D. C., can be purchased from manufacturers or large dealers.

All precautions for drying, storing, and sowing seed, as given under the dipping treatment, must be carefully followed. The seed ought to be tested for germination before being used.

(D) THE BLUESTONE (BLUE VITRIOL) TREATMENT

Materials needed—

Same as for dipping with formalin, except, instead of formalin, bluestone, or copper sulphate (also called blue vitriol), is used.

Two general modifications of this method are in common use. In one case a strong solution of the copper sulphate is used, and the seed merely dipped or sprayed; while in the other a weak solution is used and the grain soaked for a number of hours.

1. *Treatment with a Strong Solution.*—Dissolve 1 pound copper sulphate in 4 gallons of water and dip the seed, or spray it with a fine spray. The essential thing is to moisten thoroughly the entire outside of each kernel. Care should be exercised in not permitting too much of the solution to soak into the seed.

2. *Treatment with a Weak Solution.*—Use 1 pound copper sulphate to 25 gallons of water and soak the seed for about 12 hours. The solution should be stirred occasionally. The seed, after this soaking, is dipped for 5 to 10 minutes in lime-water, made in the proportion of 1 pound of quick lime to 10 gallons of water.

The treated seed may be sown on the day following treatment or it may be thoroughly dried and kept for several months. If sown the day after treatment, it will usually sprout from one to several days sooner than dry wheat. This may or may not be advantageous, according to conditions. If the seed is sown late, earlier sprouting will be very desirable; if sown very early, before danger of frost is past, it will not be desirable.

SUMMARY OF TREATMENT

Treat your seed grain by one of the methods described above. The simplest method is sprinkling with, or dipping in, a formalin solution. Hot water requires more care, but is an excellent method.

Keep your seed in clean sacks or bins.

Use a clean seeder.

Do not thresh with a separator which is smutty.

When you get new seed, be sure to remove weed seeds, and then treat for smut.

Do not let the treated seed sprout or mold.

Do not let the seed freeze while still swollen after treatment.

Allow for the swelling of the seed, if you sow the grain soon after treatment, by planting more per acre.

Remember that sacks, bins, etc., are clean only when washed with

a strong formalin, corrosive sublimate, or other solution, or when boiled in water.

Loose Smut of Wheat

The loose smut of wheat is very easily distinguished from the stinking smut. It appears very much earlier, usually as soon as the plants head out. The whole head, except the stalk, is smutted, and the smut mass breaks as soon as the head comes out of the "boot." The smut powder, which is green-black in color, is soon blown off by the wind, leaving nothing but the bare stalks. By harvest-time all of this smut has disappeared, and since it does not all appear at once, a farmer is apt to underestimate the amount. Fields with from three to five per cent of the heads attacked by this smut are not uncommon, although on the average probably less than this is found. A small amount is found in almost every wheat field. It is thus seen to be more widely distributed than the stinking smut, although it does not cause so much damage. The smut mass differs, furthermore, from the stinking smut in that it does not give off any odor and it does not form smut balls.

Sometimes, especially toward the end of the season, a smutted head bears some sound grains. These nearly always appear at the top of the head. When a plant is smutted, usually every head in that plant is affected. Sometimes, however, some or even most of the heads of a smutted plant may escape.

The infection in the flower depends somewhat on the weather conditions, so that the smut is worse in some seasons than in others. The exact effect of the weather is not fully understood. Another feature should be noted. There is no danger of infection of seed grain after harvest, such as is common in stinking smut. All of the infection by loose smut takes place in the field before harvest. Sound seed of wheat, when mixed with loose smut spores, will not become infected with this loose smut, but if sound seed is mixed with stinking smut, it will produce stinking smut almost without fail. Threshing machines can not, therefore, spread the loose smut, while they certainly can spread stinking smut.

Since this smut is carried in the seed, it is well for a farmer to know where his seed comes from. If it comes from a field which had some loose smut, he can be quite sure that it will again produce loose smut (unless he treats the seed as described below). Attention is again called to the fact that you can not detect the smut in the grain. Grain which has considerable smut in it may appear perfectly healthy, that is, it may have neither odor nor smutty color.

Although this smut is inside of the grain, it can be killed by a

severe method of seed treatment. This treatment, however, requires much care and accuracy, and the method is such that only small amounts can be treated with safety. The disease is therefore best handled by keeping your wheat fields as nearly free as possible from this smut, that is, by getting seed from fields that you know did not have smut or were not near any fields that had much smut. *Watch the source of your seed. Get seed clean inside as well as outside. This is the best method of handling this disease.*

VARIETIES

Not much difference is shown in our common wheats in regard to loose smut; durum wheats seem to have comparatively little. Of the common spring wheats of Minnesota, the bearded wheats seem to have more than the bluestems and fifes, but the differences are not great. No common variety shows any marked resistance to the disease.

TREATMENT

Recent experiments both in Europe and in this country give some hope that prolonged soaking of the seed in a strong solution of corrosive sublimate or possibly formalin will be effective in killing the smut in the seed. However, not enough work has been done to make possible the formulation of recommendations.

The method described below has, however, been thoroughly tested and is known to be effective. It is recommended only for the treatment of small amounts at one time, and is best used in connection with a special seed plat, that is, a field set aside especially for raising seed wheat, where by general selection and treatment seed wheat may be kept up to a high standard of yield and of purity from both weeds and diseases.

The following treatment is that recommended in Bulletin No. 152, Bureau of Plant Industry, U. S. Department of Agriculture:

> In general, the method to be recommended is the following: The keeping of a seed plat, the seed for which has been cleaned of smut by the application of Jensen's modified hot-water treatment, and the use of the grain from this plat for seed the succeeding year, when no further treatment is necessary. If the farm is very large it may require several years to get the smut entirely eliminated from the whole farm. This recommendation involves two processes, which will now be described.
>
> #### Selection of the Seed Plat
>
> A good, clean, well-cultivated piece of land should be selected and set aside for the raising of seed for the succeeding year. For this plat, seed should first be carefully cleaned and selected by the best fanning and sifting processes. This seed should then be treated as directed later. The plat ought to be large enough to provide at least twice as much grain as will be necessary for farm seed the following year, in order to allow for loss in cleaning and selecting. This seed plat must not be placed next to fields of smutted crops of the same cereals. The

plat ought also to be located so that the prevailing winds at flowering-time will not carry spores to the seed plat from a neighboring field of the same grain. The isolation of this plat from smutted crops of the same cereal is absolutely necessary, not only from crops on the owner's farm, but from neighboring farms as well. A strip of wood, a corn field, a large meadow, or a barley or oat field, intervening between the wheat seed plat and fields of smutted wheat, will be useful, and similarly a field of corn, oats, or wheat, or a large meadow or strip of woods between the barley seed plat and the smutted field, will be a valuable protection. This point can not be too strongly emphasized, and the coöperation of neighbors may be necessary to carry it into effect.

Treatment of the Seed for the Seed Plat

After seed for the plat has been properly cleaned, it must be treated by the Jensen method to eliminate the smut. This can be done according to the following directions: The clean seed should be soaked for from five to seven hours in water at ordinary room temperature, 17° to 22° C. (63° to 72° F.). It should be placed in small, loose sacks or wire baskets, containing not more than one-half peck each and drained for a short time. It is of the greatest importance that the seed be treated in small lots, in order that all of the grain may be quickly and uniformly brought to the desired temperature. Two tubs or vats of water should be provided. In one tub (No. 2) the exact temperature required should be maintained. The other tub (No. 1) is used for bringing the grain to the temperature of the treatment, so as not to lower the temperature in tub No. 2. Galvanized-iron tubs of 20 to 40 gallons capacity, and kerosene or gasoline double-burner stoves, are sufficient for treatment. The drained sacks or baskets of seed should be plunged into tub No. 1 for a minute, then transferred to tub No. 2, and kept agitated while immersed at temperatures and for the periods specified below; the temperatures mentioned being maintained as nearly as possible:

For barley, 15 minutes at 52° C. (125.6° F.).

For wheat, 10 minutes at 54° C. (129.2° F.).

In treating barley, if the temperature should rise above 52° C. (125.6° F.), the time of immersion must be reduced to ten minutes at 53° C. (127.4° F.) or five minutes at 54° C. (129.2° F.). Above 54° C. (129.2° F.) there is no safe margin. If the temperature falls slightly below 52° C. (125.6° F.), the time of treatment should be increased in proportion. A temperature lower than 51° C. (123.8° F.) will not be effective. In treating wheat, if the temperature should rise above 54° C. (129.2° F.), or fall below 52° C. (125.6° F.), the time for immersion must be diminished or increased accordingly. Under no circumstances should a temperature of more than 55° C. (131° F.) be allowed. Temperatures below 51° C. (123.8° F.) are ineffective.*

Seed treated as indicated may be planted as soon as it is sufficiently dry to run freely through the drills. Allowance must then be made for the swollen seed, and also for injury in treatment. The increase due to swollen seed can be estimated by measuring seed before and after treatment. The seed may be treated several months before seeding time and then dried quickly and carefully. In many cases the grain germinates as well or better, when rested after treatment, than if sown immediately. The seed may be dried by spreading it out in thin layers not over 2 inches in depth on a clean granary floor or on canvas and by shoveling or raking it from time to time. It must not be allowed to sprout. Care must be taken to prevent the freezing of the grain when it is moist, as this will impair germination.

*Two men working together can easily treat one bushel of grain an hour, or enough seed in one day to sow a seed plat from 6 to 10 acres in size.

A good thermometer should be used for all treatments.* The use of an instrument which is not accurate will result in injury to the germinating power of the grain on the one hand, or in failure to prevent the smut on the other.

Several weeks before sowing, the seed should be tested for germination. This can be done by placing several small lots of grain of 100 seeds each between damp blotters and keeping them at a living-room temperature for several days. The percentage of sprouted kernels will show the power of germination. If this is low, a corresponding increase in the rate of seeding is necessary.

The seed plat should be maintained from year to year, at least as long as any smut is present on the farm. Seed obtained from the treated seed plat does not have to be treated the following year. All fields that are free from smut must be kept separated, as previously stated, from smutted fields of the same grain. Coöperation with neighbors may be necessary to bring this about.

SUMMARY OF TREATMENT

Watch carefully for loose smut at heading-out and flowering time of the wheat.

Take your seed from fields which have little or no smut and thus keep the disease from increasing. This at least will help to keep down the smut.

Do not try to grow wheat clean of loose smut near another wheat field which you know will have loose smut, since the wind will carry the spores some distance.

Raise your seed in a seed plat and keep it free from weeds and clean of loose smut by getting and planting clean seed or treating by Jensen's modified hot-water method, and then by proper precautions keep it clean. Seed from a field clean of loose smut does not need treatment for the loose smut.

DAMAGE

Loose smut does not cause nearly as much damage in Minnesota as stinking smut. The damage is not, however, so slight that it can be entirely overlooked. First of all, it is usually underestimated, since it appears so early and again disappears before harvest. In the second place, it is very widely distributed and almost every field pays at least a small tax to this disease, so that the total loss is not small. Under favorable weather conditions the disease might easily become epidemic. When this smut is compared with stinking smut, it will be noticed that although stinking smut is not present in every field, it is more serious in those fields where it occurs. In states farther east and south, loose smut has been reported in some places as causing over 50 per cent loss

*Thermometers may be submitted to the Bureau of Standards, Washington, D. C., for test. A charge of about 50 cents will be made for testing at the two points necessary. They should be graduated in single or half degrees—Centigrade—directly upon the stem or upon a scale contained within the stem, and should preferably read from 0° to 100°. The bulbs, at least, should be made of a suitable glass, such as Jena "Normal" thermometer glass, or Corning Medium thermometer glass, in order that the readings may not change with time, and the general construction of the thermometer should be good. However, thermometers with the Bureau of Standards' certificates can be purchased directly from manufacturers or large dealers, and this is generally a much more convenient way to secure them, because it avoids the risk and expense of shipping them to and from Washington.

in some fields. It will be well, therefore, to be on the lookout for this disease. An accurate estimate of the loss in Minnesota is extremely difficult. It is probably not more than one per cent. A quarter of a million dollars a year is a conservative estimate.

BARLEY SMUTS

There are two very common smuts on barley in Minnesota. They resemble the smuts of wheat in many ways. The covered smut of barley is like the stinking smut of wheat in its late appearance, life history, and methods of treatment, while the loose smut of barley is similar to the loose smut of wheat. The loose smut of barley is, however, much more commonly found than the loose smut of wheat, and probably does more damage in Minnesota than the covered smut. It is much harder to distinguish between the covered smut and loose smut of barley than between the stinking smut and loose smut of wheat.

Covered Smut of Barley

Like the stinking smut of wheat, this is a late smut and is often found in the threshed grain in the form of black, irregular, and hard masses, as shown in Figure 10. It does not appear quite as late as stinking smut, and the affected heads are more easily recognized. Most of the chaff is smutted, as well as the kernel; and each smut ball is covered by a silvery skin, which often breaks soon after the smut heads appear. Most of the smut is in this way exposed to the wind and blown upon the healthy heads. This smut appears about two weeks after the loose smut begins to show in the field, and the smut spores of the covered smut are therefore blown upon healthy heads when the grain is filling. They probably lodge between the chaff. There does not seem to be much danger from this at or after harvest. The spores seem to get on the healthy grain in the field. Ordinarily, when barley which is free from this smut is mixed with smut balls and planted, only a little smut is produced in the crop. This seems to prove that the spores get on the grain in the field. Although this seems true, this smut is very different from the loose smut of barley, because in the covered smut the spores remain on the outside of the barley seed or between the chaff, while in the loose smut the smut plant gets inside of the grain. For this reason the formalin treatment of the barley seed readily kills the covered smut, but a special treatment is necessary for the loose smut. When barley with covered smut on it is planted, the smut grows when the seed germinates, and infects the barley plant just as described above in the second group of smuts. Seed treatment is therefore the remedy. One feature of this smut should be emphasized, viz., that since the smutting of the seed takes place mostly in the field, it will not show up in the threshing or in the threshed grain as clearly as does stinking smut of wheat. It may, therefore, easily escape notice.

TREATMENT

The formalin treatment is highly recommended, and especially the dipping treatment. This is exactly similar to that described above for the stinking smut of wheat.

Fig. 10. Loose and Covered Smuts of Barley

A Normal head and kernels.
B Head deformed by loose smut.
C Covered smut, showing the smut balls below.

The hot-water treatment can also be used, but the temperature of the water must be slightly lower than that used for wheat, because barley will not stand such high temperature as the wheat seed. The water should be kept between 125.6° and 129.2° F. during treatment, but should not go higher.

SUMMARY OF TREATMENT

Be sure, before harvesting, which smut of barley you have, and if you have the late or covered smut, you can prevent it in the next crop by treating the seed. If you are in doubt, send some heads to the Botanist, University Farm, St. Paul, for identification.

Treat the seed with formalin or as described above for stinking smut of wheat. Remember that this will not prevent the loose smut.

DAMAGE

It is impossible to say how much damage is done to barley by this smut, since there are very few farmers who realize that there are two kinds of smut on barley, and still fewer who can distinguish one from the other. All reports of smut of barley, therefore, include both kinds. The two often cause more than ten per cent loss in some fields, and in certain cases cause considerably more. It should be noted that without actually counting a large number of heads, a farmer is likely to overestimate the smut. A great many fields are found in the State with from three to five per cent injury by smut, and very few fields are entirely free from it.

At the Experiment Station numerous counts of the two smuts show that here, at least, the loose smut is much more common than the covered smut. Many counts show that it is twice as common. This may be due, however, to the fact that much of the barley has at one time or another been treated with formalin, thus reducing or destroying the covered smut without preventing the loose smut.

The two smuts on barley probably cause an average annual loss of about half a million dollars in Minnesota. The most important feature of the loss is that these smuts (at least the loose smut) seem to be on the increase. They are certainly much more abundant now than they were ten or fifteen years ago.

Loose Smut of Barley

The loose smut of barley is probably more common in the State and it is at the same time the more difficult smut to treat. It is, first of all, of the greatest importance that the farmer should be able to distinguish it from the covered smut. The following summary of differences should enable him to tell one from the other:

Loose Smut	Covered Smut
1. Comes out early; begins as soon as heads appear. Maximum smut about July 4.	1. Begins to come out about two weeks later than the loose smut. Maximum smut usually about July 12.
2. Even the awns are often converted into smut.	2. Awns are usually not smutted.
3. Smut masses break soon after coming out, and the smut is blown out by the wind, leaving only the bare stalks.	3. Smut masses may break and some may be blown out, but many of the smut balls remain on the stalk until harvest.
4. The smut mass has a dark olive-green color. The thin skin around it breaks very early.	4. The smut mass is almost coal-black in color and has a silvery gray skin around it.
5. Can not be prevented by ordinary formalin treatment.	5. Can be prevented by formalin treatment.

The life history of the loose smut of barley is exactly similar to that of the loose smut of wheat, as given on pages 42 to 44. The method of treatment is therefore similar and has been discussed. It must be borne in mind, however, that the barley must be treated at slightly lower temperatures than the wheat.

In an experiment recently made at the Wisconsin Experiment Station loose smut was almost entirely prevented by soaking the seed for two hours in a formalin solution of one pound of formalin to 40 gallons of water. However, this method of treatment has not been extensively tried and should be used at first only on small quantities.

Damage.—See remarks under Covered Smut.

OAT SMUT

There is only one common smut on oats. It is very common throughout the State. It appears almost as soon as the oats begin to head. As in most of these grain smuts, a smutted plant usually produces nothing but smutted heads, and often every grain in the plant is smutted. Sometimes one or more heads in such a plant will escape the smut, and some grains in a smutted head may also escape. The chaff as well as the kernel is usually smutted. The smut balls break soon after appearing, and the smut powder is blown away by the wind, so that at harvest time little or no smut may be seen in the oats. The smut powder is blown onto healthy heads, and probably gets in between the chaff, or it may lodge on the outside of the grain. There seems to be less danger of contaminating oats after the grain is threshed than is the case with stinking smut of wheat. This is probably accounted for by the way in which the spores are blown about in the field before the grain is ripe, giving the spores a chance to get in between the chaff. This is further emphasized by the fact that when hull-less oats are mixed with oat smut and planted, a great deal of smut is obtained. The life history of the smut is like that of stinking smut of wheat and has already been described. It should be noticed that although the smut spores may get between the chaff, the smut probably never gets inside of the kernels. Therefore the formalin treatment of the seed

will kill the smut and will usually prevent it completely. The treatments are similar to those for stinking smut of wheat.

TREATMENT

See treatment of stinking smut of wheat, but it is asserted by some investigators that the bluestone treatment should not be used for oats, as it is injurious to the seed.

Fig. 11. Oat Smut

On left, a healthy head of oats.
On right, a smutted head.

VARIETIES

Most varieties of oats planted in Minnesota are subject to smut, though there seems to be some difference in the resistance power of different varieties or strains. Not a great deal is yet known about this, except that such a difference does exist. The question of resistance is not, however, one of prime importance, since a farmer can prevent smut in any variety of oats by a very simple and cheap treatment, such as the formalin method. He can then use whatever variety may otherwise suit his purpose. In other words, if a farmer were to select his oats for smut resistance, he might have to use a variety which would not in other respects be desirable. It is best, therefore, to rely on the seed treatment to get rid of smut, rather than upon the selection of varieties.

DAMAGE

Oat smut is very common, and every farmer who raises oats is familiar with it. Losses of from two to five per cent are very common, and larger losses are frequently met. An average of two per cent for the State would probably be a very conservative estimate, and would mean a loss of about half a million dollars annually; while a loss of four per cent or one million dollars a year is probably more nearly accurate. Every cent of this loss can be avoided at a very slight expense by seed treatment.

SORGHUM SMUTS

Although sorghum, or "cane," is not one of the main agricultural crops of Minnesota, a considerable amount is raised in the State, and it is affected by at least one smut.

Head Smut

There are two known smuts of sorghum, only one of which is, however, very widely distributed. The head smut, which appears as a single large smut mass, replacing the head of grain and looking something like corn smut, is not common, if present at all, in the State. This is fortunate, since no successful treatment is yet known. Any occurrence of this smut in the State should be immediately reported to the State Experiment Station. The other smut, known as the grain smut, is quite common and is easily distinguished from the head smut, since in the grain smut each smut ball is formed in place of one grain and its chaff.

Grain Smut

Since comparatively little sorghum is raised in Minnesota for grain, this smut is often overlooked. It can be frequently found, how-

ever, in the young heads, and undoubtedly injures the sorghum, both for syrup and fodder purposes. The smut appears soon after the grain heads out. Usually every head of a smutted plant is smutted, but very frequently some of the grains in a smutted head escape. Each smut ball replaces a kernel and often the chaff. Many of the smut balls break open in the field, since the skin around the smut mass breaks readily. The smut ball can easily be broken when pressed between two fingers, showing a dark brown mass of smut powder. The life history is exactly similar to that of stinking smut of wheat already described. The treatments are also similar. Sorghum seed will, however, stand much higher temperatures of hot water without injury. This makes the hot-water treatment very easy to handle, since there is less danger of killing the seed; while the smut is just as easily killed as in wheat. The formalin treatments are, however, just as effective as in wheat, and can be highly recommended. The expense of treatment is particularly small in view of the small size of the seed and the small amounts of seed usually required. Since seed is ordinarily raised only in the southern part of the State, farmers must often rely on seed that is brought in from other localities, and hence they do not know whether or not it has smut on it. This smut is very common throughout the country, and seed from any district may have smut. It is best, therefore, to treat the seed in practically every case.

Damage.—No estimate of the loss by this smut can be made. It is probably small, but that little can be very easily avoided.

MILLET SMUT

For prevention of millet smut, follow the directions given for treatment of oat smut.

SUMMARY

The smuts of grains described above cause an annual total loss to the farmers of Minnesota estimated at three million dollars. Most of this loss can be prevented by simple and cheap treatment of the seed.

If you have stinking smut of wheat, oat smut, covered smut of barley, or sorghum grain smut, treat your seed as directed above and you can get rid of these smuts entirely.

If you have smut in your corn, be careful about the handling of the soil and particularly of the manure pile. Seed treatment for this is useless.

If you have loose smut of wheat or barley, get seed from a field without these smuts, or treat a small amount for a seed plat by the modified hot-water method.

If you can not determine from the descriptions and illustrations given above, what smut is present in your fields, send samples or communicate with the Botanist, University Farm, St. Paul.

In raising any of these crops except corn, keep on the safe side. *Always treat your seed.*

NOTE ON FORMALIN AND FORMALDEHYDE

The word formalin has been used in this Bulletin for any concentrated (about 40 per cent by weight) solution of formaldehyde gas. Such solutions can be obtained at drug stores and chemical companies under various names, such as formaldehyde, formalose, etc.

The important thing to the farmer is that he get a guaranteed solution of full strength. If there is any doubt of the strength, send a sample to the Station Chemist, University Farm, St. Paul, Minn., to be tested.